

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

APPLE INC.,
Petitioner,

v.

SPEIR TECHNOLOGIES LTD.,
Patent Owner

IPR2022-00151
Patent No. 7,110,779

**DECLARATION OF DR. MARK P. MAHON IN SUPPORT OF PATENT
OWNER'S RESPONSE**

TABLE OF CONTENTS

I.	INTRODUCTION.....	1
II.	BACKGROUND AND QUALIFICATIONS.....	2
III.	LEGAL PRINCIPLES	7
A.	Claim construction	7
B.	Burden of Proof.....	8
C.	Anticipation.....	8
D.	Obviousness	9
IV.	PERSON OF ORDINARY SKILL IN THE ART	10
V.	THE PETITION’S PROPOSED COMBINATION OF MCCRADY AND RAPHAELI	11
A.	First Combination Theory	12
B.	Second Combination Theory.....	27
VI.	THE PETITION’S PROPOSED COMBINATION OF ROFHEART AND RAPHAELI	33

I, Mark P. Mahon, Ph.D, hereby declare as follows:

I. Introduction

1. I am over the age of eighteen (18) years and otherwise competent to make this declaration.

2. I have been retained as an expert witness on behalf of Speir Technologies Ltd. (“Speir”) for the above-captioned *inter partes* review (“IPR”). I understand that the petition for *inter partes* review involves U.S. Patent No. 7,110,779 (“the ’779 Patent”).

3. I make this declaration based on my personal knowledge, educational background and training, consideration of the materials I discuss herein, and my expert opinions.

4. I am being compensated at a rate of \$475 per hour for my time in this matter. My compensation does not depend on the outcome of this proceeding, and I have no financial interest in its outcome.

5. I have been asked to consider whether the claims of the ’779 Patent would have been obvious based on certain prior art references. I have also been asked to consider the state of the art and prior art available as of January 29, 2004, the filing date of the ’779 Patent. Based on the combination of prior art references discussed in the Petition and declaration, it is my opinion that one of ordinary skill

in the art would not have found claims 1-34 of the '779 Patent to have been obvious. My opinions are provided below.

6. In preparing this Declaration, I have reviewed and considered the '779 Patent, the '779 Patent's prosecution history, the Petition, the declaration of Dr. Zhi Ding submitted in this proceeding, the deposition testimony of Dr. Ding, and each document cited in my declaration.

II. Background And Qualifications

7. My qualifications for forming the opinions given in this declaration are summarized here and are addressed more fully in my curriculum vitae, which is submitted as Exhibit 2007. That exhibit also includes a list of my publications.

8. I am a Teaching Professor in the School of Electrical Engineering and Computer Science at Pennsylvania State University, University Park, PA ("Penn State" or "PSU"). I have worked on communication networks (including AMPS, IS-95, CDMA2000, GSM, EDGE, UMTS/WCDMA, LTE, and 5G cellular), distributed sensor networks (distributed governed and autonomous), and computer networks in general since 1988.

9. I received my B.S. in Electronics Engineering from the University of Scranton in 1987. I received my M.S. in Electrical Engineering and Ph.D. in Acoustics from Penn State in 1991 and 2001, respectively.

10. In 1988, after I received my bachelor's degree, I joined the Central Intelligence Agency (CIA) while pursuing my M.S. degree at Penn State part-time. My first job at the CIA involved designing and testing systems to automatically capture and characterize telecommunication signals and emissions from various computer networking devices.

11. I returned to Penn State in early 1990 to pursue graduate research full-time and complete my M.S. degree. My graduate research work focused on wideband beamforming and adaptive signal processing. After completing my M.S. degree in EE in 1991, I accepted a full-time faculty research position at the Applied Research Lab at PSU, primarily working on classified programs, and began working on diverse radio frequency and acoustic sensor systems including wireless communications and radio frequency (RF) wireless sensor networks for atmospheric sensing, acoustic propagation prediction, acoustic tracking, source localization, and feature extraction. The acoustic tracking and source localization research focused on integrating distributed sensor reports into common track reports of wheeled and tracked vehicles and performing automatic target recognition.

12. I began pursuing my Ph.D. part-time in 1993 while continuing my faculty research position. In 1997, as part of my faculty research position, I began working on classified programs focused on mathematical analytical modeling of

communication networks and the development of hardware and software systems to test against cellular networks. My role was to develop the algorithms and write the code running on a specially developed embedded system. For this work, I received a letter of recognition as the “genius behind the VELA software algorithms” from the Director of National Reconnaissance Office (NRO) Systems Engineering and Technology Office. As part of this same work, I was extensively involved in protocol and signaling analysis as well as researching model-specific performance and unique functional characteristics associated with individual mobile devices. The work involved testing dozens of handsets from many manufacturers in controlled and real-world environments against network simulators and live operational networks for each research project..

13. In 2000 my research extended into utilizing non-orthogonal wavelets for improving detection and localization of cellular handsets from high altitude sensor systems. In 2001, I completed my Ph.D. and my research focused on the utilization of advanced communication signals for wideband characterization and remote sensing of propagation channels.

14. Beginning in 2003, I was co-principal investigator and technical lead on a 3 year multi-million-dollar research effort for developing the Global Information Grid (GIG). This project was sponsored by the Secretary of Defense’s Office with a goal of developing a real-time, multi-intelligence (multi-Int) network

for collecting, processing, storing, disseminating, and managing information on demand for decision makers including the warfighter, combatant command centers, policy makers, and support personnel and was the largest network-centric warfare project in development at the time. My research team (Ubiquitous Automated Information Manager) focused on building and deploying a scalable application to perform real-time, multi-int data fusion to support every user in the system. This software application was deployed in Combat Operation Centers, Joint Interagency Task Force locations, and on various platforms (mobile and small computing environments) used by various warfighters. The fused data sources included various content management systems, supply chain logistic reports, GPS-based reports, news feeds, backend databases, sensor system reports, and various other broad data sources.

15. I have been working on classified projects since 1988. Before 1998, because the work was not deemed highly classified, I was able to publish eight journal and conference papers prior to 2000. Between 1999 and 2015, however, I was allowed to publish only one article in an unclassified symposium and published and presented about a dozen articles in classified settings. This is because during this period, the vast majority of my research was highly classified. As a result, nearly all of my research results were summarized in classified reports and not available to the general public. Further, because the U.S. government owns

any intellectual property resulting from the sponsored research work, I did not pursue or file patent applications.

16. In 2015, I transferred to the School of Electrical Engineering and Computer Science at Penn State as a teaching faculty member. In that role, I have continued teaching graduate and undergraduate courses, guiding Ph.D. and M.S. students in communication and mobile networking (including LTE and 5G cellular networks), and pursuing research in this and related areas. Since 2015, I have been an author on seven refereed papers as listed in my curriculum vitae.

17. Because of my decades of research and my continuing work at Penn State, I have intimate knowledge of communication networks, including the wireless technologies involved in the '779 Patent and the Petition's prior art references in this case. I have been highly recognized as an expert in such systems within the research community. I was recognized twice by the National Reconnaissance Office with commendation letters (one is quoted above) for work dealing with the detection and localization of cellular signals in low signal to noise ratio environments. The U.S. government awarded me over \$12M in grants between 2003 and 2015 for projects focused on mobile communication devices and networks, in which I served as a Principal Investigator (PI), Co-PI, and/or technical lead.

18. Additionally, during my research career, I interacted extensively with computer scientists and engineers responsible for the design, development, and testing of wireless and mobile data networking systems and testbeds. As a research faculty member, I oversaw engineers and computer scientists that executed many joint projects with development organizations. These interactions exposed me to a wide range of computer scientists and engineers working on wireless and cellular technologies. Since 2011, I have been teaching undergraduate and graduate classes in communication and mobile networking and am familiar with the curricula being taught to electrical engineers and computer scientists. The interactions with a wide range of computer scientists and engineers working on telecommunication and wireless network technologies and the familiarity with the classes taught to electrical engineers and computer scientists have allowed me to have a good understanding of the level of skills possessed by a person of ordinary skill in the field of communication networks. My curriculum vitae includes a more detailed summary of my background, experience, and publications, as well as the cases in which I have served as an expert witness.

III. Legal Principles

A. Claim construction

19. I understand that the first step in performing a validity analysis of the patent claims is to interpret the meaning and scope of the claims by construing the

terms and phrases found in those claims. I understand that the appropriate construction of a claim term is its ordinary and accustomed meaning as understood by one of ordinary skill in the art at the time of the invention in the context of the entire patent.

20. I understand that standard for claim construction in an *inter partes* review is the same standard as is applied in district court proceedings.

21. I understand that a determination of the meaning and scope of the claims is a matter of law. I have been informed that to determine the meaning of the claims, one should consider the intrinsic evidence, which includes the patent's claims, written description, and prosecution history.

B. Burden of Proof

22. I understand that in an *inter partes* review, the petitioner has the burden of proving unpatentability by a preponderance of the evidence.

C. Anticipation

23. I have been instructed by counsel and understand that a reference is anticipated if a single prior art reference discloses each and every claim element, either explicitly or inherently, as arranged in the same way as in the claim. I understand that where even one claim element is not disclosed in a reference, a contention of anticipation fails.

24. I further understand that when a reference fails to explicitly disclose a claim element, that reference inherently discloses that element only if the reference must *necessarily* include the undisclosed claim element.

D. Obviousness

25. I have been instructed by counsel and understand that a combination of prior art references may render a claim obvious if, at the time of the invention, a person of ordinary skill in the art would have selected and combined those prior-art elements in the normal course of research and development to yield the claimed invention.

26. I understand that in an obviousness analysis, one should consider the *Graham* factors: the scope and content of the prior art; the differences between the claimed inventions and the prior art; the level of ordinary skill in the art; and certain secondary considerations, identified below. I further understand the obviousness analysis is to be performed on a claim-by-claim basis. I understand that a person of ordinary skill in the art is a person of ordinary creativity, not an automaton.

27. I have been instructed by counsel and understand that obviousness requires more than a mere showing that the prior art includes separate references covering each separate limitation in a claim under examination. I understand obviousness requires the additional showing that a person of ordinary skill at the

time of the invention would have been *motivated* to combine those references in a manner that would include all limitations of the challenged claim, and, in making that combination, a person of ordinary skill in the art would have had a *reasonable expectation of success*.

28. I also understand that an obviousness analysis must be conducted with awareness of the distortion caused by hindsight bias and with caution of arguments reliant upon *ex post* reasoning. For instance, I understand that when considering obviousness, I should put myself in the position of a person of ordinary skill in the field at the time of the invention, rather than considering new information that is known today but was not known before the priority date of the challenged patent.

29. In particular, I understand that it is improper to use the challenged patent's disclosure or invention as a roadmap to find its prior-art components, because such an approach discounts the value of combining various existing features or principles in a new way to achieve a new result.

IV. Person of ordinary skill in the art

30. In his declaration, Dr. Ding states that a person of ordinary skill in the art "would have had a Bachelor's degree in electrical engineering, computer engineering, computer science, or a related field, and 2-3 years of experience in design or development of wireless communication systems/networks including ranging/positioning systems, or the equivalent. Additional graduate education

could substitute for professional experience, or significant experience in the field could substitute for formal education.” Ex. 1003 at ¶ 21. The only issue I take with Dr. Ding’s assessment of the level of skill in the art is with respect to the use of degrees in computer engineering and computer science. Candidates for those degrees will not typically encounter the wireless technologies, including signal propagation and processing, at issue in the ’779 Patent and prior art references in this case. I would therefore assert that a person of ordinary skill in the art would have had a Bachelor’s degree in electrical engineering, or a related field, and 2-3 years of experience in design or development of wireless communication systems/networks including ranging/positioning systems, or the equivalent. Additional graduate education could substitute for professional experience, or significant experience in the field could substitute for formal education. For purposes of this declaration, I apply this level of skill in the art. I further note that, as of the filing date of the ’779 Patent, January 29, 2004, I was at least at this level of skill.

V. The Petition’s Proposed Combination of McCrady and Raphaeli

31. According to the assertions in the Petition and Dr. Ding’s declaration, a POSITA would be motivated to incorporate Raphaeli’s teachings about averaging propagation delays into McCrady’s system under two combination theories. Under the first theory a “POSITA would have calculated the individual

propagation delays (delay estimates) from the “M” ranging message exchanges on various frequencies, and then averaged those delays as taught by Raphaeli.”

Petition at 8-9. Under the second theory, “[t]he POSITA would have contemplated the alternative approach of conducting multiple of McCrady’s ranging message exchanges on a single frequency, determining corresponding delays, and averaging those delays as taught by Raphaeli.” Petition at 9-10.

A. First Combination Theory

32. The first combination theory may be summarized as “average range estimates across carriers.” I address the necessary technical background material and address this “average range estimates across carriers” theory below.

33. U.S. Patent No. 6,453,168 (“McCrady”) is directed to “a position location system for determining the position of a mobile communication device, and, more particularly, to a system employing two-way transmission of spread spectrum ranging signals between the mobile communication device and reference communication devices having relatively low accuracy clocks, to rapidly and accurately determine the position of the mobile communication device in the presence of severe multipath interference.” Ex. 1005, 1:9-17.

34. McCrady also discloses that the targeted context for the invention is for “rapidly and accurately determin[ing] the physical location of a mobile

communications device” for military, emergency response (such as firefighters or medical personnel), and search and rescue. *Id.*, 1:15-16, 1:19-35.

35. McCrady further discloses as motivation for the invention that relying on GPS-based satellites or ground transmitters to determine accurate and operational position location of a device may be “severely degraded in the presence of multipath interference.” *Id.*, 1:15-16; *see also id.* 2:13-16, 3:46-51. Thus, McCrady asserts that an objective of the invention is to “rapidly, reliably, and accurately determine the three-dimensional position of a mobile communication device in a variety of environments... where multipath interference can be great.” *Id.*, 3:54-58. Furthermore, McCrady adds that “another objective of the present invention to minimize the interference caused by multipath signal propagation ... thereby providing highly accurate three-dimensional position estimates even under severe multipath conditions.” *Id.*, 3:66–4:3.

36. McCrady also states that “with the present invention[] a ... device provides accurate, reliable position information within **milliseconds** ... [and] is capable of determining position location to an **accuracy of less than one meter** in a **severe multipath environment**.” *Id.*, 6:20-27 (emphasis added). To accomplish its goals with respect to accuracy, McCrady further describes that the system (i) “perform[s] internal delay calibration” in both the master radio and the reference radio to minimize difficult-to-predict internal transmitter and receiver delay

variation, *id.*, 10:36-43, 10:64-11:2, 11:40-43; (ii) uses “state of the art spread spectrum chipping rates and bandwidths to reduce multipath interference,” *id.*, 4:10-13, 5:13-17; (iii) performs “[l]eading edge curve fitting [] to accurately locate the leading-edge of an acquisition sequence ... to further reduce effect of multipath interference on TOA estimates,” *id.*, 5:17-20; and (iv) uses, “[i]f necessitated by severe multipath, **frequency diversity ... to orthogonalize multipath interference** with respect to direct path signal, **wherein an optimal carrier frequency is identified and used to estimate the TOA to minimize the impact of multipath interference**” *id.*, 5:22-27 (emphasis added).

37. A POSITA reading McCrady’s disclosures would understand that the invention is directed to accurate, reliable, fast, high resolution position localization even in high multipath environments where it discloses, for a high accuracy mode operating in severe multipath conditions, the use of frequency diversity to identify and utilize **an optimal carrier frequency** to perform the TOA estimation. “On the other hand, if the multipath interference is classified as substantial and the high accuracy (e.g. one meter) mode has been selected, the TOA processor implements a process employing frequency diversity to identify an optimal transmission frequency that minimizes multipath interference.” *Id.*, 14:35-40.

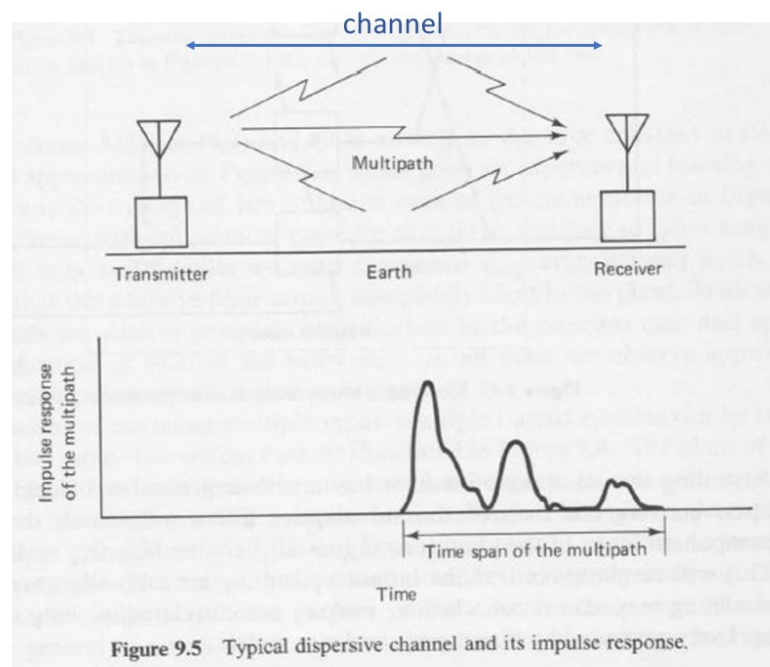
38. McCrady discloses that the reference radios or the master radio can declare the need for frequency diversity. When the need for frequency diversity has

been declared, “the master radio identifies the set of M carrier frequencies that will be used to transmit a sequence of M outbound ranging messages and M corresponding reply ranging messages (block 102) ... These frequencies are referred to as “ping” frequencies, since a rapid succession of M different frequency signals or multiple “pings” are transmitted between the radios **in search of an optimal frequency.**” *Id.*, 14:46-56 (emphasis added).

39. McCrady supports this technical approach by pointing out that “[r]anging performance is best when the carrier phase of the multipath is 90° with respect to the direct path. If this orthogonality condition is met, the direct path and multipath are separated such that the direct path and multipath can be more precisely curve fit with minimal effects for multipath.” *Id.*, 14:60-65. A POSITA would understand McCrady to disclose using frequency diversity to find **an optimal frequency** as a necessary technical component to achieve the benefits of the invention’s TOA estimation techniques in a multipath environment because “ping frequencies ... [are used] to find the frequency that best orthogonalizes the phase of the multipath interference with respect to the direct signal.” *Id.*, 15:8-13..

40. A POSITA would understand that multipath “is a problem in which the transmitted information takes more than one path to the receiver, thus producing interference and echoes in the received signal” which in turn leads to time-dispersion of the received signal. Ex. 2008, *Adaptive Signal Processing*,

Widrow and Stearns, at pg. 200. As shown in the annotated figure below, the time-dispersive nature of the received signal is characterized by the impulse response of the channel where the “impulse” is referring to an idealized zero-width transmitted pulse (Dirac-delta function), *i.e.*, how the transmitted signal (impulse) appears in amplitude and phase at the receiver.



Ex. 2008, *Adaptive Signal Processing*, Widrow and Stearns, at pg. 200.

41. A POSITA would also understand that the impulse response characterizes the time-response of the channel and is valid for the period of time over which the time and frequency characteristics of the channel are considered to be constant. A POSITA would also understand that the channel impulse response can vary over time due to the changing time and frequency characteristics of the channel. There are many factors, environmental and otherwise, that will affect the

variation of the time and frequency characteristics of the channel over short (and longer) periods of time. Consequently, these factors will affect the period of time over which the time and frequency characteristics of the channel are considered to be constant.

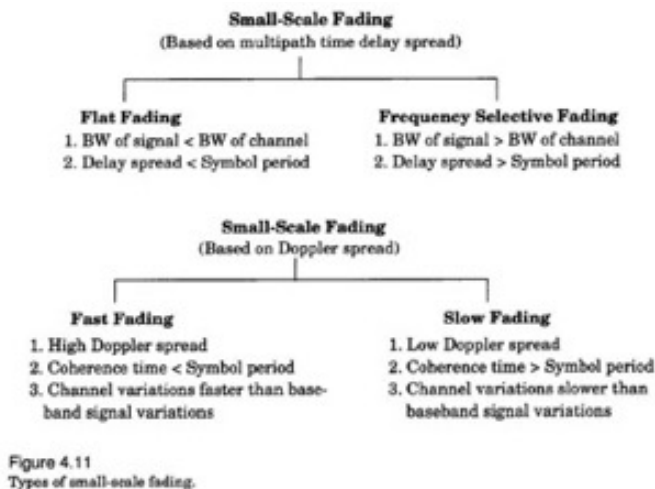
42. In a multipath environment, the rapid changes of the amplitude and phase of a received signal over a short time window is known as fading and are the result of multiple signal components arriving via different propagation paths that may add destructively at the receiver. “Small-scale fading, or simply *fading*, is used to describe the rapid fluctuation of the amplitude of a radio signal over a short period of time or travel distance...Fading is caused by interference between two or more versions of the transmitted signal which arrive at the receiver at slightly different times. These waves, called *multipath waves*, combine at the receiver to give a resultant signal which can vary widely in amplitude and phase, depending on the distribution of the intensity and relative propagation time of the waves and the bandwidth of the transmitted signal.” Ex. 2009, *Wireless Communications Principles & Practices*, Rappaport, at pg. 139. The main small-scale fading effects that multipath causes on the received signal are three-fold: (1) rapid changes in signal strength over a short time interval; (2) random frequency modulation due to Doppler shifts on each separate multipath signal; and (3) time dispersion (echoes

or apparent time spread as seen in the Widrow and Stearns figure above) caused by relative delays between each multipath propagation component. *Id.*

43. Additionally, it is understood to a POSITA that mobile radio propagation is a complex and varied topic that involves two specific engineering approaches in capturing the characteristics of a given channel. The first is instantaneous measurements. The second is statistical characterization using many time averaged instantaneous measurements of the channel to associate the channel's behavior with a statistical model of multipath fading. *See* Ex. 2010, *Digital Communications Over Fading Channels, A Unified Approach to Performance Analysis*, Simon and Alouini, at pp. 15 – 28, Ex. 2011, *Digital Communications*, Fourth Edition, Proakis, at pp. 810–820.

44. With respect to multipath, there are several physical elements of the propagation channel that create the small-scale fading effects: (i) the multipath propagation itself which is caused by reflection, refraction, and scattering occurring in the channel and is due to natural and manmade objects in the channel as well as other factors; (ii) the relative motion of the transmitter and receiver which imparts random, time varying frequency modulation (Doppler shifts) onto a given multipath component; and (iii) the relationship between the bandwidth of the signal and the bandwidth of channel (coherence bandwidth) which can cause distortion (but not significant fading) of the transmitted signal if the former is

greater than the latter (if, however, the signal bandwidth is less than the channel bandwidth, the signal distortion will be negligible or minimal, but the amplitude may vary significantly (fading)). Ex. 2009, *Wireless Communications Principles & Practices*, Rappaport, at pp. 140-141. The small-scale fading effects are summarized in the diagram below:



Id., at pg. 167.

45. Generally, statistical models help a POSITA to predict the maximum and minimum fade a signal with a given bandwidth in a given frequency range might experience under given propagation conditions associated with the channel. However, for specific challenging channel conditions (channel model), a POSITA would have to rely on several signal processing methods to improve the reception quality, *i.e.*, the likelihood of detecting the transmitted signal, in these challenging conditions. “Mobile Communication systems require signal processing techniques

that improve the link performance in hostile mobile radio environments.” *Id.*, at pg. 299. “Equalization, diversity, and channel coding are three techniques which can be used independently or in tandem to improve received signal quality.” *Id.* As to the first, an equalizer can be used in a receiver to compensate for signal distortion (spreading in time) to mitigate intersymbol interference (the overlap of the received symbols due to the time spreading of individual symbols). As to the second, spatial, time, and frequency diversity are techniques employing multiple antennas, multiple separate transmissions of the same signal, and more than one carrier respectively. As to the third, channel coding typically brings to bear convolutional codes to assist in correcting detected bit errors at the receiver. *See, e.g., Ex. 1006, Raphaeli, 19:1-10.*

46. A POSITA would therefore have been aware that to mitigate multipath fading, “[o]ne method is to employ *frequency diversity*. That is, the same information bearing signal is transmitted on L carriers, where the separation between successive carriers equals or exceeds the coherence bandwidth $(\Delta f)_c$ of the channel.” Ex. 2011, *Digital Communications*, Proakis, at pg. 821. Systems using this frequency diversity technique will implement what is known as “protection switching,” where if one of the carriers being utilized is experiencing a deep fade, the system will switch over to using another carrier offset by more than the known coherence bandwidth of the channel. *See Ex. 2009, Wireless Communications*

Principles & Practices, Rappaport, at pg. 335, Ex. 2012, *Digital Modulation Techniques*, Xiong, at pg. 562.

47. A second, well known, “more sophisticated” technique utilizing frequency diversity is to transmit a signal having a bandwidth much greater than the coherence bandwidth of the channel. In this case, only one information bearing signal is transmitted, but across a frequency range **known to be wider** than the coherence bandwidth of the channel. “Such a signal with bandwidth W will resolve the multipath components and, thus, provide the receiver with several independently fading signal paths.” This approach utilizes a specific receiver architecture (known as a RAKE receiver) to optimize the system performance. *See* Ex. 2011, *Digital Communications*, Proakis, at pp. 821–822; Ex. 1009, Rofheart, 11:66-12:27. A RAKE receiver involves combining multiple copies of the received signal to essentially average out statistically independent fades associated with each multipath component. This is in contrast to the previous frequency diversity approach discussed above in which the multiple copies of the signal are transmitted on narrower bandwidth carriers.

48. McCrady specifically chooses to implement frequency diversity of the first variety to deal with the hostile radio environment: “if the multipath interference is classified as substantial and the high accuracy (e.g., one meter) mode has been selected, the TOA processor implements a process employing

frequency diversity to identify an optimal transmission frequency that minimizes multipath interference.” Ex. 1005, 14:35-40. A POSITA would understand that this is consistent with McCrady’s disclosed system and is a design choice that is matched to the specific implementation to **optimize performance**. “[T]he master radio identifies the set of M carrier frequencies that will be used to transmit a sequence of M outbound ranging messages and M corresponding reply ranging messages (block 102).” *Id.*, 14:46-49. McCrady further states, “These frequencies are referred to as “ping” frequencies, since a rapid succession of M different frequency signals or multiple “pings” are transmitted between radios in search of an **optimal frequency**.” *Id.*, 14:53-56 (emphasis added). McCrady’s system is using multiple messages transmitted in time-step wise parallel fashion to perform a **selection of a single frequency** to use for that given signal transmission and **thus select a single optimum instance** (which copy of a signal is received best on a given one of the M carriers) to perform the range estimation calculation.

49. McCrady holds that “[r]anging performance is best when the carrier phase of the multipath is 90° with respect to the direct path. If this orthogonality condition is met, the direct path and multipath are separated such that the direct path can be more precisely curve fit with minimal effects for multipath.” *Id.*, 14:61-65. Consequently, “[u]pon completion of the M trials, the frequency having the best multipath discrimination is identified (block 112) and a leading edge curve

fit 114 is performed on the output of the corresponding matched filter to estimate the TOA. Specifically, the data is searched to find the frequency where the **optimal pulsewidth** occurs at the **carrier phase with the shortest path delay**. The resulting TOA measurement is processed in the aforementioned manner to accurately determine the range between the master radio and the reference radio, and the range estimate and TOA accuracy estimate are supplied to the navigation Kalman filter to update the master radio's position." *Id.*, 15:36-47 (emphasis added).

50. A POSITA would understand these statements to provide the technical reasoning and support for McCrady's disclosure of a high accuracy, reliable, fast technique for **finding an optimal multipath condition on a single carrier**. A POSITA would also understand that this approach is consistent with McCrady's use of curve fitting to determine time of arrival and, thus, make an optimal range estimation without the need for taking many repeated instantaneous measurements and using some statistical approach to average those multiple measurements together. This is because, by definition, and consistent with the knowledge of a POSITA of multipath small-scale fading and the system disclosed by McCrady, **using multiple copies of the signals received on the M carriers would lead to a suboptimal result** (greater range estimation error and non-shortest path result).

51. If you have an optimal pulse width result with the shortest path length from 1 out of M possibilities and you average it with a second result that is not optimal and/or non-shortest path length, the result must necessarily be less than optimal as measured by the system. If there is a case where there are multiple, equally optimal results, then averaging does not provide any additional benefit and only adds both complexity to the receiver side of the radio design and time delay to the overall calculation of a ranging result.

52. Additionally, since McCrady utilizes a Kalman filter to perform position tracking and state estimation across time to account for measurements derived from non-direct path measurements that would bias the range estimate to be a large value than the direct path estimate. *See id.*, 14:15-18, 15:42-47. That is, McCrady uses a significantly more complex filter than a moving average for position tracking using optimized instantaneous range estimates. Ex. 2013, *Signal Processing for Intelligent Sensor Systems*, Swanson, at pp. 277 – 292; Ex. 2011, *Digital Communications*, Proakis, at pp. 683-688.

53. Contrary to the Petition's and Dr. Ding's assertion, a POSITA would not be motivated to combine the teachings of McCrady and Raphaeli to calculate the individual propagation delays from the M ranging message exchanges on various frequencies as taught by McCrady, and then average those delays as taught by Raphaeli for several substantive technical reasons.

54. First, as discussed above, the result obtained on an “optimal carrier frequency,” determined from the set of the M carriers, with another result obtained from the same set of carriers using a suboptimal carrier frequency (determined as disclosed in McCrady via an orthogonality metric), would be known to result in a suboptimal result to one of ordinary skill in the art.

55. Second, even if the averaged results were of exactly the same optimality, the result would not be an improved range estimate, it would at best be identical and at worst would bias the range estimate since McCrady discloses that “the data is searched to find the frequency where the optimal pulsewidth occurs at the carrier phase with the shortest path delay” Ex. 1005, 15:40-42. This may be the case when two paths being averaged together are not both dominated by the direct path signal. The resulting range estimate for a non-direct path signal would be longer than an estimate from a carrier that has a corresponding direct path measurement, and is therefore an optimal frequency. Averaging in a range estimate from a multipath that did not have a direct path component would result in a larger overall range estimate (due to longer path delay and the addition a positive bias to the range estimate). Furthermore, McCrady utilizes another step of implementing a Kalman filter for making state estimates to account for differing range estimates from time step to time step due to a biasing factor such as longer propagation path

lengths that are calculated when the direct path component is not present on the optimal carrier.

56. Third, the increased complexity and time delays associated with implementing a ranging step goes against the teachings of McCrady that the system utilizing “communication devices ... to rapidly and accurately determine the position of the mobile communication device ...” *Id.*, 1:14-16.

57. Fourth, in order to implement a frequency diversity technique that would offer the opportunity to average together multiple received signals with uncorrelated fading to obtain a higher quality estimate of the received signal, would require a design change that guaranteed the transmitted signal’s bandwidth was able to be modified on the fly to be significantly greater than the coherence bandwidth of the channel and it would require additional receiver structure such as a RAKE correlator. However, this would still result in a single propagation delay estimate being made from the averaged received signal rather than averaging together multiple propagation delay estimates from the individual received signal each independently suffering from some deep fade effect. This is consistent with a POSITA’s understanding that McCrady specifically discloses a choice to implement a particular frequency diversity technique for mitigating severe multipath in harsh mobile propagation conditions while simultaneously providing rapid, accurate range estimates.

B. Second Combination Theory

58. The Petition's second theory may be summarized as "average multiple range estimates on a single carrier." I address technical background material (in addition to the material presented above) and address this proposed second combination theory below.

59. I note that the Petition only refers to this second combination theory as generally relating to a single carrier frequency. In his declaration, Dr. Ding adds that "[t]his single frequency could be, for example, a default frequency or selected based on McCrady's M ranging message exchanges on different frequencies." Ex. 1003, ¶ 78. My opinion does not change with respect to either of Dr. Ding's approaches.

60. As detailed above, McCrady's disclosures are directed to making a fast (on the order of "milliseconds") and accurate range estimation measurement in severe multipath environments. The Petition's first theory would not motivate a POSITA to combine McCrady with Raphaeli because it would result in worse performance, provide biased results, and require a significant redesign with unpredictable results. To address the Petition's second theory, a POSITA would look to their understanding of small-scale fading due to severe multipath conditions in a channel and how the channel would change over time with respect to a single carrier.

61. As discussed previously, a multipath environment induces a time dispersive characteristic in the received signal as depicted in Exhibit 2008, *Adaptive Signal Processing*, Widrow and Stearns, Fig. 9.5 for a single transmitted pulse. Due to the time-varying nature of fading multipath channel, the impulse response of Fig. 9.5 may change significantly from pulse transmission to pulse transmission (i.e., from one transmission of the ranging reply to a subsequent repeated transmission of the same ranging reply message). As an example, the figure below shows how the same pulse transmitted at different time steps may manifest varying time dispersion at the receiver.

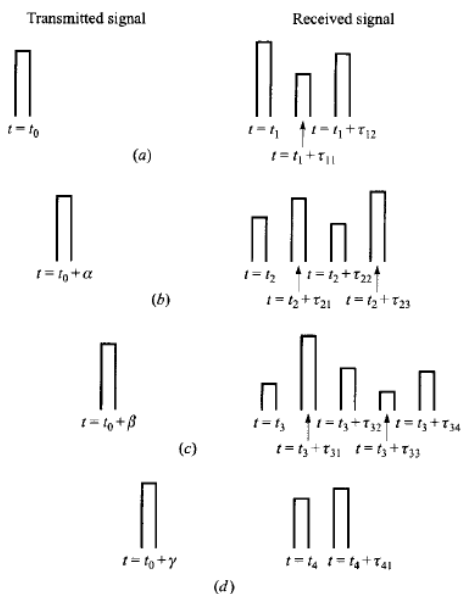


FIGURE 14.1-1
Example of the response of a time-variant multipath channel to a very narrow pulse.

Ex. 2011, *Digital Communications*, Proakis, at pg. 801.

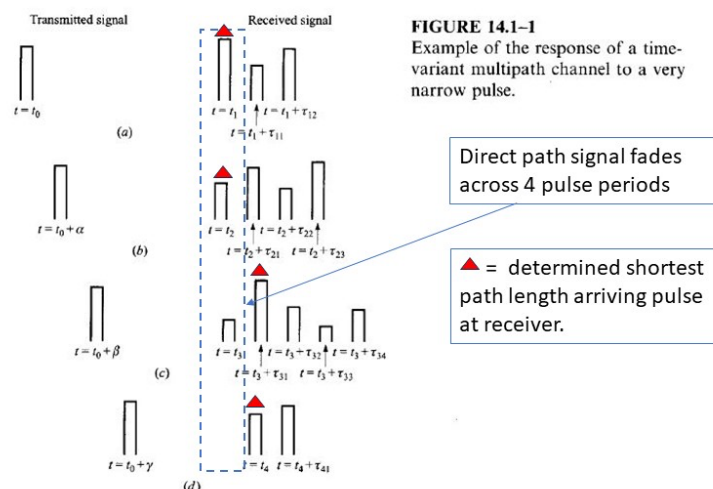
62. An identical time-width pulse (transmitted signal) is transmitted at successive time steps (a), (b), (c), and (d). The received signal, due to the multipath

conditions at the instant the pulse is transmitted, manifests different time dispersed copies of the transmitted signal (“echoes”) at each respective time step. This is because, as discussed above, the characteristics of the channel that lead to distortion of the transmitted pulse/signal (no distortion is depicted in the figure above) and multiple copies of the transmitted signal appearing at the receiver (due to multipath) change over time.

63. McCrady discloses a frequency diversity approach by transmitting M copies of the “outbound ranging messages” on each of M carriers. “The selection of the number M of ping frequencies and the individual ping carrier frequencies can be determined in any of a number of ways. For example, a fixed number of carrier frequencies ... at set frequencies covering a predetermined frequency range can be used (e.g., carrier frequencies at 2 MHz increments covering a 15 MHz range).” Ex. 1005, 14:66-15:5. As depicted in Fig. 4.11 from Exhibit 2009, *Wireless Communications Principles & Practices*, Rappaport, above in ¶ 44, severe multipath can result in either frequency selective fading (if the bandwidth of the signal is greater than the coherence bandwidth of the channel which is more likely when transmitting one wideband signal) or in flat fading when the bandwidth of the signal is less than the coherence bandwidth of the channel. A POSITA would understand that *frequency diversity*, as previously discussed above,

is a signal processing technique that may be brought to bear to mitigate these issues.

64. Sending the ranging signal at “carrier frequencies at 2Mhz increments covering a 15 MHz range”, for example, would likely lead to some of the carriers experiencing less multipath distortion (i.e., the bandwidth of the signal is less than the coherence bandwidth of the channel in these cases) but still subject to *flat fading*. Flat fading is known to a POSITA to occur when “the multipath structure of the channel is such that the spectral characteristics of the transmitted signal are preserved at the receiver. However, the strength of the received signal changes with time, due to fluctuations in the gain of the channel caused by multipath.” Ex. 2009, *Wireless Communications Principles & Practices*, Rappaport, at pg. 168. An annotated version of Fig. 14.1-1 from Exhibit 2011, *Digital Communications*, Proakis, is shown below.



65. As highlighted in the figure at time step (a) three copies of the signal arrive at the receiver. In McCrady's system, if this figure represented the "optimal frequency" from the M carriers and the system continued to track this same optimal carrier at time steps (b), (c), and (d) (i.e., based upon the original determination that this was the optimum carrier, under the Petition's second theory the system would make multiple measurements on this same carrier), the first arriving copy of the signal at time step (a) is strong and would give the shortest path delay so that pulse would be used to make the range estimation. As the time steps progress, depending upon how many measurements are used, the amplitude decays due to flat fading would cause later arriving pulses to be used (for example in (c) and (d)), biasing the originally determined shortest path delay to average to a larger path delay estimate. A POSITA would therefore understand that a pulse with a lower received amplitude is going to lead to a large estimation error creating a lower accuracy result than what would be optimum under McCrady's disclosed system where the best of M candidates is chosen rather than the same carrier under successive measurements.

66. The Petition's second combination theory, "average multiple range estimates on a single carrier," regardless of the single carrier frequency that could be chosen, adds uncertainty with respect to McCrady's disclosure of finding "the

frequency where the optimal pulsewidth occurs at the carrier with the shortest path delay.” Ex. 1005, 15:40-42. A POSITA would not be motivated to combine Raphaeli to integrate an inferior approach that will likely add higher range estimation error and require additional system design and/or signal processing to provide signal and system checks to determine if a particular measurement instance should or should not be included on a specific carrier, rather than implementing McCrady’s original approach which would provide an optimum solution at each measurement instance. Additionally, as under the first combination theory, this second combination theory would add delay in providing an estimate which goes against the McCrady’s “rapid, accurate” teachings and add uncertain performance and outcomes based on forcing the system to only use a given carrier over multiple time steps.

67. The Petition’s second combination theory also removes additional flexibility with respect to McCrady’s frequency diversity process. In McCrady, “TOA processing occurs in both the reference radio upon reception of the outbound RTS-T ranging message and in the master radio upon reception of the reply TOA ranging message.” Ex. 1005, 13:17-20. “[A]t the reference radio the TOA estimate is used to accurately determine the turn around time,” which is reported back to the master radio for use in the range estimation. *See id.*, 9:5-23. Depending on the severity of the multipath at any given time, the shortest path

delay for the outbound RTS-T ranging message, as reflected in the estimation process for the time of arrival at the reference radio, may occur at a different one of the M carrier frequencies than the shortest path delay for the reply message, as reflected in the estimation process for the time of arrival at the master radio. While McCrady does not specifically discuss the use of different carrier frequencies for the time of arrival estimations at the reference radio and the master radio, it does not foreclose that possibility, which under certain conditions could provide a more accurate range estimation. Modifying McCrady under the second theory would foreclose a technique that provides lower estimation error. A POSITA would not be motivated to combine Raphaeli for this additional reason.

VI. The Petition's Proposed Combination of Rofheart and Raphaeli

68. According to the assertions in the Petition and Dr. Ding's declaration, a POSITA would be motivated to incorporate Raphaeli's teachings about averaging propagation delays into Rofheart's system under a single combination theory. Petition at 54-57.

69. Ultra wide band systems provide high range resolution. Rofheart describes an ultra wide band system with range resolution being on the "order of centimeters." See Ex. 1009, 17:1-12, 18:34-44. Rofheart does state that "an ultra wide bandwidth system having 3 GHz of bandwidth has a range resolution of 1 meters," Ex. 1009, 17:4-6, but I believe the "1 meters" to be a typographical error.

First, “meters” is in the plural, which is inconsistent with a unitary identification. In other words, “1 m” would be “1 meter,” not “1 meters.” Second, “1 meters” is somewhat inconsistent with Rofheart’s description of resolution being “on the order of centimeters” and a POSITA would understand that propagation speed (3×10^8 m/s) divided by frequency (3×10^9 Hz) would result in 0.1m as a range resolution estimate. Finally, other patent applications in the same family more accurately recite “an ultra wide bandwidth system having 3 GHz of bandwidth has a range resolution of 0.1 meters.” Ex. 2006, U.S. Patent Application Publication 2003/0174948 to McCorkle, at [0097] (continuation in part of Rofheart). I note that 0.1 meters is 10 centimeters, which is less than 4 inches.

70. Rofheart’s system is designed to be deployed in relatively confined environments such as conference rooms and retail stores. Ex. 1009, 2:29-48. With the confined environment and the high range resolution the Rofheart ultra wide band system provides, a POSITA would not see any discernable benefit from incorporating Raphaeli’s teachings about averaging propagation delays into Rofheart. For example, a ten-percent (10%) improvement would result in the range estimation changing by about $\frac{3}{8}$ ”.

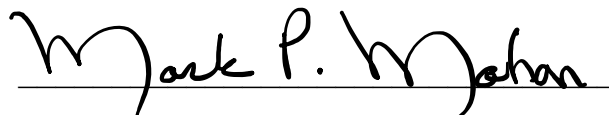
71. Moreover, incorporating Raphaeli’s teachings about averaging propagation delays into Rofheart would require Rofheart’s local device to double its allocation of transmit time resources for purposes of obtaining multiple

propagation delay estimates. This extra utilization of transmit time resources, which would come at the expense of substantive data communications between the local device and enabled remote devices, is inconsistent with Rofheart's goal of minimizing the allocation of transmit time resources to distance determining messages. Ex. 1009, 22:19-25.

72. Balancing the negligible benefits provided by incorporating Raphaeli's teachings about averaging propagation delays into Rofheart against the drawback of lost transmit time resources for substantive data communications, a POSITA would not be motivated to make the proposed combination.

I declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true.

August 28, 2023


Mark P. Mahon, Ph.D.